The Mysore Agricultural Journal

(The Organ of the Mysore Agricultural and Experimental Union)

Vol. XXIV] 1945-46 [No. 4

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Vol. XXIV] 1945—46 [No. 4

A Note on Wind Power and Its Utilisation for Food Production in Mysore State[1]

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Introduction

A review of the available data on production and consumption of food in Mysore State[2] confirmed that the Government with the help of the huge quantities of food grains imported, has been providing quantities as rations which are not very much lower than what we were used to on an average during the pre-war days. But the necessity for increased production of food grains by all possible means is immediate. For without imports, an additional area of nearly ten lakhs and fifty thousand acres may have to be brought under food grains during next year (provided we are blessed with normal seasonal conditions) to feed the population as usual, postponing at present the proposed post-war problem of improving the diet of the people. This problem is serious because nearly 84% of the cultivated area in the state is at the mercy of rainfall and in the arid parts of the State less than 10% of the area has been protected by irrigation. This is particularly so in Chitaldrug district and some of its adjacent places where only 6% of the area is irrigated. A large percentage of this irrigated area is also indirectly dependent on the scanty (and highly variable) rainfall.

In Chitaldrug, Bangalore, Kolar and Tumkur districts, tanks and wells have been an important source for irrigation. Much experimental work appears to be necessary from the agricultural and irrigational point of view. Geologists have found (and agriculturists have realised much earlier) that the north-eastern portion of the State has a special hydrographical feature in the large number of spring heads or *Talapariges*. Lewis Rice states, " These (*talapariges*) extend throughout the border regions situated east of a line drawn from Koratagere to Hiriyur and Molakalmuru. When the water is obtained, it is either conducted by narrow channels

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[1] I am grateful to Mr. M. A. Srinivasan, B.A., Minister for Agriculture, for having suggested this problem.

My thanks are due to Mr. M. J. Narasimhan, B.A., Director of Agriculture, and Mr. K. H. Srinivasan, M.A., B.Sc. (Edin.), Deputy Director of Agriculture, for their encouragement and the facilities given to me.

[2] " Production and Consumption of Food in Mysore, Parts I, II, III," *Mysore Economic Journal*, Vol. 32, Nos. 2, 3, Feb., March 1946.

to the fields or a *Kapile* well is constructed from which water is lifted by bullocks". Electric and other pumps for lifting water from the wells have been in use on a very limited scale. Mechanical means of lifting water from wells are available but somehow they have not been in use. Rice attributes the absence of wind mills to the prevailing lightness of the wind in general. In the light of the increased knowledge we have in Agricultural Meteorology and the improved types of wind mills reported to be available, an investigation into the possibilities of utilising the available wind power for lift irrigation in certain places appears to be necessary. The present note is an attempt to review the available data and may be of some use for the above investigation. A discussion of the wind velocity data for many places in India has been published by Mr. V. Doraswamy Iyer.[3]

Part I. Wind Power in Mysore State

Data on daily wind velocities are available for each month for forty years (from 1905) for four places—Bangalore, Mysore, Hassan and Chitaldrug, for six years for Jogimatti (Chitaldrug district) and for three years for Balehonnur (Kadur district). Average daily wind velocities in miles[4] are given in Table I.

It is seen that the wind velocities differ in the different places which is due chiefly to the topographical features. Jogimatti experiences very high winds while Balehonnur has very low winds. Mysore, Bangalore and Chitaldrug usually have medium to high winds, while low winds are present at Hassan. In general, wind velocities are maximum during June-July and minimum in October. A secondary maximum and minimum exists during December-January and March-April respectively. Average daily maximum and minimum wind velocity values are given below in the tabular statement for the six places.

Locality	Maximum daily wind velocity and the period	Minimum daily wind velocity and the period
Bangalore ..	212 miles in July and 128 miles in January	103 miles in October and 108 miles in April
Mysore ..	205 miles in July and 146 miles in December	105 miles in October and 107 miles in March
Hassan ..	186 miles in July and 70 miles in January	67 miles in November and 70 miles in February
Chitaldrug ..	197 miles in July and 105 miles in January	86 miles in October, Nov. and 89 miles in February
Jogimatti ..	274 miles in July and 210 miles in December	188 miles in March and 195 miles in October
Balehonnur ..	94 miles in July and 74 miles in January	53 miles in October and 53 miles in March

[3] *Scienific Notes, India Meteorological Department*, Vol. VI, No. 63.

[4] Necessary corrections have been applied for data on wind velocity for the years 1905 to 1911, by using the correction factor of 2·2 instead of 3·0.

Further, the average number of days in each month when the daily wind velocities were

(*a*) below 120 miles (*i.e.*, average of 5 miles per hour);

(*b*) between 120 and 240 miles (*i.e.*, between the averages of 5 and 10 miles per hour) and

(*c*) above 240 miles (*i.e.*, average of 10 miles per hour and above),

are given for Bangalore, Mysore, Hassan and Chitaldrug (average of 34 years), for Jogimatti (average of 3 years) and for Balehonnur (average of 6 years) in Table II of the appendix. Below are given the averages for the year.

Locality→ Daily Wind Velocity ↓	Average number of days for the year at					
	Bangalore	Mysore	Hassan	Chitaldrug	Jogimatti	Balehonnur
Less than 120 miles ..	189	151	211	182	24	330
Between 120 and 240 miles	168	190	141	169	231	35
Above 240 miles ..	8	24	13	14	110	..
Above 120 miles ..	176	214	154	173	341	35

From the above table it is obvious that medium to high velocities of wind (120 miles per day and above) prevail for an appreciable number of days (ranging from 154 to 341 days) in the year in all places excepting at Balehonnur. This indicates that attempts can be made to utilise these winds for purposes of driving the windmills. Improved types of lighter windmills are reported to be available which will work efficiently in such winds. It is now necessary to have an idea of the average duration on each day in each month when wind velocities of sufficient magnitude (to drive the windmills) are available in the different places, for the above statements are only indicative of the average daily wind velocity. It is a common experience that they are never uniform throughout the day. Studies have shown that wind velocity changes continuously and has a definite maximum and minimum. Unfortunately, data on hourly wind velocities are not available for all places except at Bangalore, where Anemographic records are being taken from a long time. From the records of the past 40 years at Bangalore, an attempt is made to estimate the hourly average wind velocities for each month for all the six places (assuming that the trends are similar). These estimates are given in Tables III to VIII.

The general trend for the year is that the wind velocity rapidly increases from a minimum in the early morning (6 A.M.) to a maximum in the afternoon (between 11 A.M. and 1 P.M.). Then it gradually decreases in the evening (7 P.M.) to a secondary minimum and again increases to a secondary maximum in the night (11 P.M.). This trend, however, differs slightly depending on the season of the year as well as the place. The two maxima occur in

the afternoon (between 11 A.M. and 1 P.M.) and in the night (between 9 P.M. and midnight) respectively, of which the former is higher.

Tables III to VIII are very helpful in arriving at an idea of the possible number of hours on each day every month when windmills could be worked at these six places of the State. For ready reference, a statement is prepared showing the frequencies of the average (average of 40 years for Bangalore, Hassan, Mysore and Chitaldrug; 6 years for Jogimatti and of 3 years for Balehonnur) number of hours per day in each month when wind velocities will be

(*a*) 4 miles and less than 4 miles per hour,
(*b*) between 4·1 and 8 miles per hour,
(*c*) between 8·1 and 10 miles per hour, and
(*d*) above 10 miles per hour.

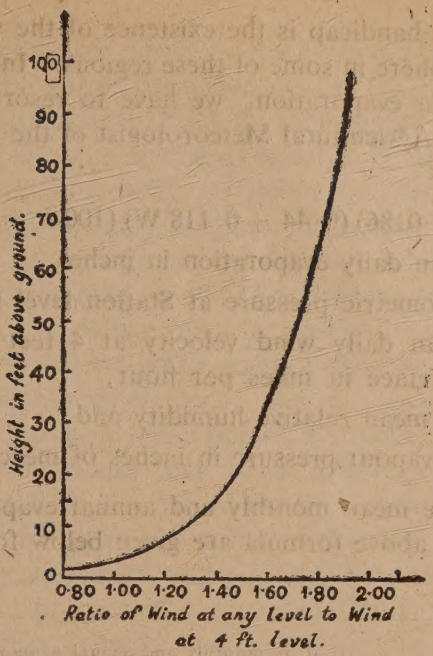
and these are given in Table IX of the appendix.

This statement will be useful to choose the most suitable wind mill which can make the maximum use of the most prevalent wind velocities for the maximum duration on each day every month.

It is seen from Table IX that on an average every year (the distribution within the year being given in Table X) it is possible to get as many as 7608 hours at Bangalore, 7645 hours at Mysore, 4586 hours at Hassan, 6012 hours at Chitaldrug, 8760 hours at Jogimatti and 310 hours at Balehonnur with wind velocities above 4·1 miles per hour. Improved types of wind mills are reported to be available which begin to work at wind velocities of about 4 miles per hour. It is obvious that this wind power is being wasted at present. An idea of the probable quantities of water that can be lifted from wells of normal capacity in each of the localities by making use of the wind power and the acreage that can be cultivated for food crops will be useful and much experimental work on this is necessary.

Another interesting and useful fact that should be remembered in this connection is that in general wind velocity in all localities increases in speed with the height above ground-level—rapidly at first and then more gradually. The exact relationship between height and the increase in wind velocity has been theoretically worked at Poona and confirmed by actual observations. The curve taken from the Scientific Note referred to indicating this relationship is given below. This fact should be useful in choosing at each locality the type of wind mill and the height at which it should be installed so as to obtain the maximum utility at a time when water for irrigation is necessary.

These facts show clearly the possibility of utilising either the commonly prevailing medium velocities or higher wind velocities for a longer duration every day. It is unfortunate, we have no experimental data on this aspect for some of the very important places particularly in the arid regions of the State. However it is a common experience for one to meet with very much higher wind velocities in areas like the eastern portions of the Chitaldrug district, some portions of Mysore, Bangalore, Hassan, Chitaldrug and Kadur



districts than what has been recorded by the Anemometer due chiefly to the topographical features. So that the possibilities for using windmills more effectively in such regions appear to be greater.

It is also necessary to have an idea of the maximum wind velocity that these places experience in cyclonic weather in order to device protective measures for the wind mills from being damaged or blown off.

Part II. Rainfall and Evaporation

In order to appreciate the necessity for protecting as much land as possible in the arid regions of Mysore State, it would be necessary to have an idea of the quantity and distribution of rainfall as well as the evaporation. But unfortunately data on evaporative power of the atmosphere is not being collected for any of these regions.

A statistical study of the rainfall of the State[5] pointed out the peculiar features about the rainfall of certain regions and the gradual (and significant) downward trend in the rainfall of certain places. The annual rainfall of the districts—Chitaldrug, Tumkur and Kolar is 23, 27 and 29 inches respectively. But the very high variability of the rainfall (23%, 25% and 24% respectively for Chitaldrug, Tumkur and Kolar districts) indicates the chances of droughy periods occurring. Rainfall in some portions of this region is mostly concentrated in the months June-July and September-October, of which that in the latter period is more and depended upon by the dry-land cultivators.

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[5] A note on the statistical study of rainfall of *Mysore State Scientific Notes*, Vol. VII, No. 71, India Meteorological Department.

Another serious handicap is the existence of the very high evaporative power of the atmosphere in some of these regions. In the absence of actual experimental data on evaporation, we have to resort to theoretical value as calculated by the Agricultural Meteorologist of the Government of India. The formula used is

$$E = (1 \cdot 465 - 0 \cdot 0186)\,(0 \cdot 44 + 0 \cdot 118\,W)\,(100/h - 1)\,e$$

where E = Mean daily evaporation in inches,

B = Barometric pressure at Station level in inches,

W = Mean daily wind velocity at 4 feet level above ground surface in miles per hour,

h = the mean relative humidity and

e = the vapour pressure in inches of mercury.

Estimates of the mean monthly and annual evaporation in inches[6] as calculated from the above formula are given below for Bangalore, Hassan and Chitaldrug.

Month	Mean monthly and annual evaporation inches at		
	Bangalore	Hassan	Chitaldrug
January ..	5·39	4·50	10·60
February ..	5·91	3·98	10·89
March ..	8·87	6·29	14·35
April ..	7·59	5·19	11·19
May ..	7·22	6·42	9·49
June ..	5·40	3·27	7·05
July ..	4·31	2·60	5·30
August ..	4·09	2·64	5·45
September ..	3·63	2·61	4·92
October ..	3·91	3·16	5·58
November ..	4·29	3·57	6·69
December ..	4·62	3·60	8·09
	65·23	47·83	99·60

The Agricultural Meteorologist states that the above values represent the evaporative power of the atmosphere with respect to a free surface of water at 4 feet above ground. But, evaporation in relation to crop-production is slightly different in that two other major factors namely evaporation from the soil surface and transpiration from plants have to be considered. While the former is purely a physical process, the latter is influenced by the physiological processes of the plants. But we have no data for our regions regarding any of these aspects. Accurate experiments on the water-requirements of crops, duty of water, etc., are necessary to evaluate some of these factors.

[6] *Scientific Notes*, Vol. VI, No. 61. India Meteorological Department.

However, the evaporative power of the atmosphere as indicated by the figures given in the table shows the seriousness of the part played by evaporation and indicates the extent to which the atmosphere is thirsty particularly at Chitaldrug. Here, the atmosphere is capable of absorbing as much as 99·6 inches of water standing on the ground in the course of one year while the mean annual rainfall is only 23 inches. It is obvious that under these circumstances rainfall of more than fifty per cent. of the days is ineffective and not available for crop-production. This can be appreciated better by looking at the averages of daily rainfall for some of the taluks of Chitaldrug district. The rainfall is fairly continuous (but very low—less than 30 cents) only in the period September-October. But the peculiar feature of this, affecting crop-production is that this period is followed by a long spell of dry weather—cold at first and very warm afterwards. Hence, the high variability of the rainfall of this period should dishearten any one because one season of low rainfall of failure of rain during this period causes much distress due to the dry period following. All these show that these regions of the State require to be protected to the maximum extent by irrigation. Completion of irrigation projects and installation of electric pumps for lift—irrigation may take some time. In the meanwhile, possibilities to utilise the available wind power in some places for lifting water from wells by means of wind mills appear to exist.

TABLE I

Average daily wind velocity[1] in miles in each month at Bangalore, Mysore, Hassan,[2] Chitaldrug, Jogimatti and Balehonnur[2]

Place	Jan.	Feb.	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Year
Bangalore ..	127·6	119·1	115·9	108·2	139·0	206·7	211·7	183·9	140·9	108·5	108·8	121·1	140·5
Mysore ..	139·1	109·1	106·9	110·5	139·9	203·6	205·3	178·3	142·3	103·3	115·3	140·2	141·8
Hassan ..	70·4	69·6	80·8	100·3	138·4	128·1	186·1	162·5	135·6	83·3	67·5	69·1	107·6
Chitaldrug ..	104·6	88·8	90·0	98·0	142·0	188·3	196·8	177·3	137·7	85·7	85·7	101·7	124·7
Jogimatti ..	203·7	194·4	188·3	191·3	217·3	256·0	273·7	252·7	224·0	194·7	203·3	210·0	217·5
Balehonnur ..	74·3	62·8	62·0	52·5	55·0	65·2	93·8	66·7	58·5	52·5	64·2	72·7	65·0

x^1 Till the year 1912 factor 3 was being used as the relation between the speed of the wind and the rate of movement of the anemometer cups. Subsequently it was found that this factor was 2·2. In this note all velocities published prior to 1912 have been converted by using the figure 2·2 instead of 3.

x^2 Average of 23 years for Bangalore, of 33 years for Mysore, Hassan and Chitaldrug. of 3 years for Jogimatti and of 6 years for Belehonnur have been used.

TABLE II

Average number of days in each month with wind velocities

(*a*) Below 120 miles per day.
(*b*) Between 120 and 240 miles per day.
(*c*) Above 240 miles per day.

For 1. Bangalore (Average of 23 years from 1912—1934)
2. Mysore (do do 1912—1934)
3. Hassan (do do 1912—1944)
4. Chitaldrug (do do 1912—1944)
5. Jogimatti (do 3 do 1913—1938)
6. Balehonnur (do 6 do 1913—1938)

No. of days with daily wind velocities	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1, BANGALORE													
Less than 120 miles per day ..	17	18	22	26	16	3	3	4	14	23	23	20	189
Between 120 and 240 miles per day ..	14	10	9	4	15	24	25	25	16	8	7	11	168
More than 240 miles per day ..	..	..	..	..	..	3	3	2	..	..	..	..	8
2. MYSORE													
Less than 120 miles per day ..	12	18	21	19	11	2	2	5	12	21	17	11	151
Between 120 and 240 miles per day ..	17	9	10	11	19	22	22	23	17	10	12	16	190
More than 240 miles per day ..	2	1	..	..	1	6	7	3	1	..	1	2	24
3. HASSAN													
Less than 120 miles per day ..	28	27	28	22	10	2	1	3	10	25	27	28	211
Between 120 and 240 miles per day ..	3	1	3	8	20	25	24	26	19	6	3	3	141
More than 240 miles per day ..	..	..	..	..	1	3	6	2	1	..	..	..	13
4. CHITALDRUG													
Less than 120 miles per day ..	18	22	24	23	11	2	2	3	11	23	23	20	182
Between 120 and 240 miles per day ..	13	6	17	7	19	24	23	25	19	8	7	11	169
More than 240 miles per day ..	..	..	..	..	1	4	6	3	..	..	..	..	14
5. JOGIMATTI													
Less than 120 miles per day ..	4	2	3	3	3	1	..	..	1	3	..	4	24
Between 120 and 240 miles per day ..	18	22	22	22	18	14	14	16	19	22	27	17	231
More than 240 miles per day ..	9	4	6	5	10	15	17	15	10	6	3	10	110
6. BALEHONNUR													
Less than 120 miles per day ..	28	26	29	30	31	28	24	27	26	27	25	29	330
Between 120 and 240 miles per day ..	3	2	2	..	..	2	7	4	4	4	5	2	35
More than 240 miles per day ..	..	..	..	..	..	..	..	..	..	..	..	..	..

TABLE III

Average estimated (of 6 years from 1933 to 1938) hourly wind velocity in miles per hour at Balehonnur (Kadur District)

Month	1	2	3	4	5	6	7	8	9	10	11	12 Noon	13	14	15	16	17	18	19	20	21	22	23	24 Midnight
January ..	3·0	2·4	2·8	2·6	2·5	2·5	2·4	2·8	3·9	3·6	3·7	3·9	3·5	3·7	3·6	3·5	3·4	2·9	2·5	2·7	2·9	3·1	3·1	3·3
February ..	2·6	2·5	2·3	2·2	1·9	1·8	1·7	2·0	2·7	2·8	2·9	3·1	3·1	3·1	3·0	2·9	2·9	2·6	2·1	2·5	2·9	3·0	3·0	3·1
March ..	2·5	2·2	1·8	1·7	1·6	1·5	1·4	1·8	2·3	2·5	2·6	3·0	3·2	3·3	3·3	3·3	3·1	2·9	2·5	2·7	3·1	3·1	3·1	3·1
April ..	2·2	2·0	1·8	1·8	1·6	1·5	2·1	2·2	2·2	2·0	2·2	2·4	2·5	2·6	2·7	2·7	2·5	2·2	2·2	2·3	2·4	2·4	2·3	1·6
May ..	2·4	2·4	2·3	2·2	2·1	2·0	2·2	2·5	2·6	2·5	2·5	2·5	2·4	2·3	2·4	2·4	2·3	2·2	1·9	1·8	2·0	2·0	2·3	2·4
June ..	2·4	2·4	2·3	2·2	2·2	2·2	2·3	2·7	3·0	3·1	3·3	3·3	3·3	3·3	3·2	3·1	3·7	2·9	2·6	2·5	2·5	2·5	2·4	2·5
July ..	3·4	3·3	3·3	3·3	3·2	3·2	3·3	3·7	4·2	4·3	4·5	4·9	4·9	4·9	4·8	4·7	4·5	4·2	3·8	3·5	3·5	3·5	3·4	3·5
August ..	2·4	2·5	2·3	2·4	2·2	2·3	2·4	2·7	3·1	3·2	3·4	3·5	3·5	3·5	3·4	3·2	3·1	2·8	2·5	2·4	2·4	2·4	2·5	2·5
September	2·4	2·3	2·3	2·2	2·1	2·1	2·2	2·5	2·8	2·8	2·9	3·0	2·9	2·9	2·9	2·7	2·5	2·2	1·9	1·9	2·1	2·2	2·3	2·3
October ..	2·0	1·9	1·8	1·8	1·7	1·7	1·9	2·2	2·6	2·7	2·8	2·9	2·8	2·8	2·7	2·6	2·4	1·9	1·7	1·8	1·9	1·9	1·9	2·0
November	2·4	2·3	2·3	2·2	2·1	2·1	2·2	2·8	3·3	3·3	3·5	3·5	3·4	3·3	3·3	3·0	2·7	2·2	2·3	2·4	2·5	2·5	2·5	2·5
December	2·9	2·9	2·8	2·7	2·7	2·7	2·7	3·3	4·0	4·0	3·9	4·0	3·9	3·8	3·7	3·6	3·3	2·7	2·5	2·7	2·9	2·9	2·9	2·9
Average for the year	2·5	2·4	2·4	2·3	2·2	2·1	2·2	2·6	3·1	3·2	3·1	3·3	3·3	3·3	3·2	3·1	2·9	2·6	2·4	2·4	2·6	2·6	2·6	2·6

TABLE IV

Average estimated hourly wind velocity at Chitaldrug

Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24 Midnight
January ..	4·3	4·0	3·9	3·7	3·6	3·5	3·4	3·9	5·4	5·1	5·2	5·5	4·9	5·2	5·1	4·9	4·7	4·0	3·5	3·8	4·1	4·3	4·3	4·3
February ..	3·7	3·5	3·2	3·2	2·7	2·5	2·4	2·9	3·9	3·9	4·2	4·4	4·4	4·4	4·3	4·2	4·0	3·6	3·0	3·5	4·0	4·3	4·3	4·0
March ..	3·6	3·2	2·6	2·5	2·4	2·2	2·1	2·7	3·4	3·6	3·7	4·3	4·6	4·8	4·9	4·8	4·6	4·2	3·7	4·0	4·5	4·6	4·4	4·5
April ..	4·2	3·7	3·4	3·4	3·1	2·9	2·9	4·1	4·2	3·8	4·2	4·4	4·6	4·8	5·1	5·1	4·6	4·2	4·2	4·3	4·4	4·4	4·3	3·1
May ..	6·2	6·2	6·0	5·8	5·5	5·3	5·6	6·4	6·7	6·6	6·4	604	6·2	6·0	6·0	6·2	5·8	5·6	5·0	4·7	5·1	5·8	6·0	6·3
June ..	6·9	6·8	6·7	6·5	6·5	6·5	6·7	7·7	8·8	8·9	9·5	9·6	9·6	9·5	9·3	9·1	8·0	8·3	7·5	7·1	7·2	7·4	7·1	7·1
July ..	7·2	7·0	6·9	6·8	6·7	6·6	6·9	7·7	8·8	9·1	9·3	10·3	10·4	10·3	10·1	9·9	9·5	8·7	7·9	7·3	7·4	7·3	7·2	7·3
August ..	6·4	6·5	6·1	6·4	5·8	6·1	6·3	7·2	8·2	8·5	9·0	9·4	9·4	9·2	9·0	8·6	8·2	7·5	6·7	6·4	6·4	6·4	6·6	6·5
September	5·6	5·4	5·3	5·2	5·1	4·9	5·1	5·8	6·6	6·7	6·8	7·1	6·9	6·9	6·8	6·4	5·9	5·2	4·5	4·5	4·9	5·2	5·3	5·3
October ..	3·3	3·1	3·0	2·9	2·8	2·7	3·0	3·7	4·2	4·3	4·6	4·7	4·6	4·6	4·5	4·2	3·9	3·0	2·8	3·0	3·0	3·1	3·2	3·3
November	3·2	3·1	3·1	2·9	2·9	3·8	2·9	3·7	4·4	4·4	4·6	4·6	4·5	4·4	4·3	4·0	3·6	2·9	2·9	3·1	3·2	3·3	3·4	3·3
December	4·0	4·0	3·9	3·8	3·7	3·7	3·8	5·6	5·6	5·6	5·5	5·6	5·3	5·3	5·0	5·6	4·6	3·7	3·8	3·8	4·0	4·1	4·1	4·1
Total ..	58·6	56·5	54·1	53·1	50·8	49·6	51·1	60·4	70·2	70·5	73·0	76·3	75·6	75·4	74·5	72·4	67·4	61·9	55·2	55·5	58·2	60·2	62·5	59·1
Average for the year	4·9	4·7	4·5	4·4	4·2	4·1	4·3	5·0	5·8	5·9	6·1	6·4	6·3	6·3	6·2	6·0	5·6	5·2	4·6	4·6	4·8	5·0	5·2	4·9

Month	1	2	3	4	5	6	7	8	9	10	11	12 Noon	13	14	15	16	17	18	19	20	21	22	23	24 Midnight
January ..	5·2	4·9	4·8	4·5	4·3	4·2	4·1	4·8	6·6	6·2	6·4	6·7	5·9	6·3	6·2	6·0	5·8	4·9	4·3	4·6	5·1	5·2	5·3	5·2
February ..	5·0	4·7	4·3	4·2	3·6	3·4	3·2	3·8	5·2	5·3	5·6	5·9	5·9	5·9	5·8	5·6	5·4	4·9	4·1	4·7	5·4	5·8	5·8	5·4
March ..	4·7	4·1	3·4	3·3	3·1	2·8	2·7	3·4	4·4	4·7	4·9	5·6	6·0	6·2	6·3	6·1	5·9	5·4	4·7	5·1	5·8	5·9	4·7	5·8
April ..	4·6	4·1	3·8	3·7	3·4	3·2	4·2	4·5	4·6	4·2	4·6	4·9	5·1	5·3	5·6	5·6	5·1	4·6	4·6	4·7	4·9	4·9	4·7	3·4
May ..	6·1	6·0	5·8	5·6	5·4	5·2	5·5	6·2	6·6	6·4	6·3	6·3	6·1	5·9	5·9	6·1	5·7	5·5	4·9	4·6	5·0	5·6	5·9	6·2
June ..	7·6	7·5	7·4	7·1	7·1	7·1	7·4	8·5	9·7	9·7	10·4	10·6	10·6	10·4	10·3	10·0	8·7	9·1	8·2	7·8	7·9	8·1	7·7	7·8
July ..	7·7	7·5	7·5	7·3	7·2	7·1	7·4	8·3	9·5	9·8	10·1	11·1	11·2	11·1	10·8	10·7	10·2	9·4	8·5	7·8	7·9	7·9	7·7	7·8
August ..	6·7	6·8	6·4	6·7	6·0	6·4	6·6	7·5	8·5	8·8	9·4	9·7	9·8	9·6	9·4	8·9	8·5	7·7	7·0	6·7	6·7	6·7	6·9	6·8
September	5·7	5·5	5·5	5·3	5·2	5·0	5·2	6·0	6·7	6·8	7·0	7·3	7·0	7·0	7·0	6·5	6·0	5·3	4·7	4·7	5·0	5·3	5·4	5·5
October ..	4·0	3·8	3·6	3·5	3·4	3·3	3·7	4·4	5·1	5·3	5·5	5·6	5·6	5·5	5·4	5·1	4·7	3·7	3·4	3·6	3·7	3·8	3·8	4·0
November	4·1	4·0	4·0	3·7	3·6	3·5	3·6	4·7	5·6	5·6	5·9	5·9	5·8	5·6	5·4	5·1	4·5	3·7	3·6	3·9	4·1	4·2	4·3	4·2
December	4·8	4·8	4·6	4·6	4·5	4·3	4·5	5·4	6·7	5·7	6·6	6·6	6·6	6·4	7·1	5·9	5·6	4·5	4·1	4·5	4·8	4·9	4·9	4·9
Total ..	66·2	63·7	61·1	59·5	56·8	55·7	58·1	67·5	79·2	79·5	82·7	86·2	85·6	85·2	84·2	81·6	76·1	68·7	62·1	62·7	66·3	68·3	68·1	67·0
Average for the year	5·5	5·3	5·1	5·0	5·6	4·6	4·8	5·6	6·6	6·6	6·9	7·2	7·1	7·1	7·1	6·8	6·3	5·7	5·2	5·2	5·5	5·7	5·7	5·6

TABLE VI

At Mysore

Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	20	19	21	22	23	24 Midnight
January ..	5·6	5·3	5·2	4·9	4·7	4·6	4·5	5·2	7·2	6·7	6·9	7·3	6·5	6·9	6·7	6·5	6·3	5·4	4·7	5·1	5·5	5·7	5·8	5·7
February ..	4·6	4·3	3·9	3·9	3·3	3·1	3·0	3·5	4·7	4·8	5·1	5·5	5·5	5·5	5·3	5·1	5·0	4·5	3·7	4·3	5·0	5·3	5·3	5·0
March ..	4·3	3·8	3·1	3·0	2·8	2·6	2·5	3·2	4·0	4·3	4·5	5·2	5·5	5·7	5·8	5·7	5·4	5·0	4·4	4·7	5·3	5·4	5·3	5·3
April ..	4·7	4·2	3·9	3·8	3·5	3·3	4·3	4·6	4·7	4·3	4·7	5·0	5·2	5·4	5·7	5·7	5·2	4·7	4·7	4·8	5·0	5·0	4·8	3·5
May ..	6·1	6·1	5·9	5·7	5·0	5·2	5·5	6·3	6·6	6·5	6·3	6·3	6·1	5·9	5·9	6·1	5·7	5·5	4·9	4·6	5·1	5·7	5·9	6·2
June ..	7·5	7·4	7·3	7·0	7·0	7·0	7·3	8·3	9·5	9·9	10·2	10·4	10·4	10·3	10·1	9·8	8·6	8·9	8·1	7·7	7·7	8·0	7·6	7·7
July ..	7·5	7·3	7·2	7·1	7·0	6·9	7·2	8·1	9·2	9·5	9·7	10·8	10·8	10·8	10·5	10·4	9·9	9·1	8·3	7·6	7·7	7·6	7·5	7·6
August ..	6·5	6·6	6·2	6·5	5·8	6·2	6·4	7·2	8·2	8·5	9·1	9·4	9·5	9·3	9·1	8·6	8·2	7·5	6·8	6·5	6·5	6·5	6·7	6·6
September	5·8	5·6	5·5	5·4	5·2	5·1	5·3	6·0	6·8	6·9	7·0	7·3	7·1	7·1	7·0	6·6	6·1	5·3	4·7	4·7	5·1	5·3	5·5	5·5
October ..	4·0	3·8	3·7	3·6	3·5	3·4	3·7	4·5	5·2	5·3	5·6	5·7	5·7	5·6	5·5	5·2	4·8	3·7	3·5	3·7	3·7	3·8	3·9	4·1
November	4·4	4·2	4·2	3·9	3·9	3·8	3·9	5·0	5·9	5·9	6·3	6·3	6·1	5·9	5·7	5·4	4·9	4·0	3·9	4·2	4·4	4·4	4·6	4·5
December	5·8	5·8	5·6	5·5	5·4	5·4	5·5	6·6	8·1	8·1	7·9	8·0	7·9	7·7	7·4	7·2	6·7	5·4	5·0	5·5	5·8	5·9	5·9	5·9
Total ..	68·8	64·4	61·7	60·3	57·5	56·6	59·1	69·5	80·1	80·4	83·3	87·2	86·3	86·1	84·7	82·3	76·8	69·0	62·7	63·4	66·8	68·6	68·8	67·6
Average for the year	5·7	5·4	5·1	5·3	4·8	4·7	4·9	5·8	6·7	6·7	6·9	7·3	7·2	7·2	7·1	6·9	6·4	5·7	5·2	5·3	5·6	5·7	5·7	5 ·6

TABLE VII

Average estimated (of 6 years from 1933 to 1938) hourly wind velocity in miles per hour at Hassan

Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24 Midnight
January ..	2·9	2·7	2·6	2·5	2·4	2·3	2·3	2·6	3·6	3·4	3·5	3·7	3·3	3·5	3·4	3·3	3·2	2·7	2·4	2·6	2·8	2·9	2·9	2·9
February..	2·9	2·7	2·5	2·5	2·1	2·0	1·9	2·2	3·0	3·1	3·3	3·5	3·5	3·5	3·4	3·3	3·2	2·9	3·1	2·7	3·2	3·4	3·4	3·2
March ..	3·3	2·9	2·3	2·3	2·1	2·0	1·9	2·4	3·0	3·3	3·4	3·9	4·2	4·3	4·4	4·3	4·1	3·8	3·3	3·5	4·0	4·1	4·0	4·0
April ..	4·3	3·8	3·5	3·4	3·1	3·0	3·9	4·2	4·3	3·9	4·3	4·5	4·7	4·9	5·2	5·2	4·7	4·3	4·3	4·4	4·5	4·5	4·4	3·1
May ..	6·1	6·0	5·8	5·6	5·3	5·1	5·5	6·2	6·5	6·4	6·3	6·3	6·1	5·1	5·9	6·1	5·7	5·5	4·9	4·5	5·0	5·6	5·9	6·1
June ..	4·7	4·6	4·6	4·4	4·4	4·4	4·6	5·3	6·0	6·0	6·4	6·5	6·5	6·5	6·3	6·2	5·4	5·6	5·1	4·8	4·9	5·0	4·8	4·8
July ..	6·8	6·6	6·6	6·5	6·3	6·3	6·5	7·3	8·3	8·6	8·8	9·8	9·8	9·8	9·5	9·4	8·9	8·3	7·5	6·9	7·0	6·9	6·8	6·9
August ..	5·9	6·0	5·6	5·9	5·3	5·6	5·8	6·6	7·5	7·8	8·3	8·6	8·6	8·5	8·3	7·8	7·5	6·8	6·2	5·9	5·9	5·9	6·1	6·0
September	5·5	5·3	5·3	5·1	5·0	4·9	5·0	5·7	6·5	6·6	6·7	7·0	6·8	6·8	6·7	6·8	5·8	5·1	4·5	4·5	4·9	5·1	5·2	5·3
October ..	3·2	3·0	2·9	2·8	2·7	2·7	2·9	3·5	4·1	4·2	4·4	4·5	4·5	4·4	4·3	4·1	3·8	2·9	2·7	2·9	2·9	3·0	3·1	3·2
November	2·5	2·5	2·5	2·3	2·2	2·2	2·2	2·9	3·5	3·5	3·7	3·7	3·6	3·5	3·3	3·1	2·9	2·3	2·2	2·4	2·5	2·6	2·7	2·6
December	2·7	2·7	2·6	2·6	2·5	2·5	2·6	3·1	3·8	3·8	3·7	3·8	3·7	3·6	3·5	3·4	3·1	2·5	2·4	2·6	2·7	2·8	2·8	2·8
Total ..	50·8	48·8	46·8	45·9	43·4	43·0	45·1	52·0	60·1	60·6	62·8	65·8	65·3	65·2	64·2	62·5	58·3	52·7	48·6	47·7	50·3	51·8	52·1	50·9
Average for the year	4·2	4·1	3·9	3·8	3·6	3·6	3·8	4·3	5·0	5·1	5·2	5·5	5·4	5·4	5·3	5·2	4·9	4·4	4·1	4·2	4·2	4·3	4·3	4·2

TABLE VIII

At Jogimatti

Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24 Midnight
January ..	8·3	7·8	7·6	7·2	6·9	6·7	6·6	7·3	10·5	9·9	10·2	10·7	9·5	10·1	9·9	9·6	9·2	7·9	6·8	7·4	8·1	8·4	8·5	8·4
February..	8·2	7·7	7·0	6·9	5·9	5·6	5·3	6·2	8·5	8·5	9·1	9·7	9·7	9·7	9·4	9·1	8·8	8·0	6·6	7·6	8·8	9·4	9·4	8·8
March ..	7·6	6·7	5·5	5·3	5·0	4·6	4·4	5·6	7·1	7·6	7·9	9·1	9·7	10·1	10·2	10·0	9·6	8·8	7·7	8·3	9·3	9·6	9·3	9·3
April ..	8·1	7·3	6·7	6·6	6·0	5·7	7·5	8·1	7·4	8·1	8·6	8·9	9·4	9·9	9·9	8·9	8·1	8·1	8·4	8·6	8·6	6·4	8·0	6·0
May ..	9·5	9·5	9·1	8·8	8·4	8·1	8·6	9·7	10·3	10·1	9·9	9·9	9·5	9·2	9·2	9·5	8·9	8·6	7·7	7·1	7·9	8·8	9·2	9·6
June ..	9·4	9·3	9·2	8·8	8·8	8·8	9·2	10·5	11·9	12·0	12·9	13·1	18·1	12·9	12·7	12·4	10·8	11·2	10·2	9·7	9·7	10·0	9·6	9·7
July ..	10·0	9·7	9·7	9·5	9·3	9·2	9·6	10·8	12·2	12·6	13·0	14·4	14·5	14·4	14·0	13·8	13·2	12·1	11·0	10·1	10·3	10·2	10·0	10·1
August ..	9·1	9·3	8·8	9·1	8·2	8·8	9·0	10·3	11·6	12·9	13·3	13·4	13·4	13·1	12·9	12·2	11·6	10·6	9·6	9·1	9·1	9·1	9·4	9·3
September	9·1	8·8	8·7	8·5	8·2	8·0	8·3	9·5	10·7	10·9	11·1	11·6	11·2	11·2	11·1	10·4	9·6	8·4	7·4	7·4	8·0	8·4	8·6	8·7
October ..	7·5	7·1	6·7	6·6	6·4	6·3	6·9	8·3	9·6	9·9	10·4	10·6	10·5	10·4	10·1	9·6	8·9	6·9	6·4	6·7	6·9	7·1	7·2	7·6
November	7·7	7·5	7·5	6·9	6·7	6·6	6·7	8·8	10·4	11·0	11·0	10·8	10·4	10·1	9·5	8·6	7·0	6·7	7·3	7·7	10·4	7·8	8·0	7·9
December	8·3	8·3	8·0	7·9	7·7	7·7	7·8	9·5	11·6	11·6	11·4	11·5	11·4	11·1	10·6	10·3	9·5	7·7	7·2	7·8	8·3	8·5	8·5	8·5
Total ..	102·8	99·0	94·5	92·1	87·5	86·1	89·9	104·8	122·5	123·8	128·3	133·6	132·2	132·2	130·1	126·3	117·6	105·3	95·4	96·9	102·7	105·9	106·1	103·9
Average																								

TABLE IX

Average number of hours per day in each month when the hourly wind velocity was under certain ranges of velocity

Place and month	Different range of hourly wind velecity	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Bangalore	4 miles and less than 4 miles ..	..	4	6	5	..	..	..	..	..	14	9	..	38
	Between 4·1 and 8 miles ..	24	20	18	19	24	11	12	15	24	10	15	24	216
	Between 8·1 and 10 miles ..	..	..	..	..	..	8	5	9	..	..	..	..	22
	Above 10 miles per hour ..	..	..	..	..	..	5	7	..	..	..	..	..	12
Mysore	4 miles and less than 4 miles ..	..	7	6	5	..	..	..	..	..	13	6	..	37
	Between 4·1 and 8 miles ..	24	17	18	19	24	11	12	15	24	11	18	22	215
	Between 8·1 and 10 miles ..	..	..	..	..	..	8	7	9	..	..	..	2	26
	Above 10 miles per hour ..	..	..	..	..	..	5	5	..	..	..	..	..	10
Hassan	4 miles and less than 4 miles ..	24	24	18	8	..	..	..	..	..	16	24	24	138
	Between 4·1 and 8 miles ..	..	..	6	16	24	24	14	19	24	8	..	..	135
	Between 8·1 and 10 miles ..	..	..	..	..	..	..	10	5	..	..	..	..	15
	Above 10 miles per hour ..	..	..	..	..	..	..	..	..	..	..	..	..	..
Chitaldrug	4 miles and less than 4 miles ..	10	16	13	8	..	..	..	..	..	16	17	11	91
	Between 4·1 and 8 miles ..	14	8	11	16	24	15	14	19	24	8	7	13	169
	Between 8·1 and 10 miles ..	..	..	..	..	..	9	10	5	..	..	..	..	28
	Above 10 miles per hour ..	..	..	..	..	..	..	..	..	..	..	..	..	..
Jogimatti	4 miles and less than 4 miles ..	..	..	..	..	..	..	..	..	..	..	..	..	..
	Between 4·1 and 8 miles ..	10	10	12	9	3	..	..	..	4	14	14	8	84
	Between 8·1 and 10 miles ..	10	14	10	15	19	12	8	13	12	5	3	8	129
	Above 10 miles per hours ..	4	..	2	..	2	12	16	11	8	5	7	8	75
Balehonnur	4 miles and less than 4 miles ..	24	24	24	24	24	24	14	24	24	24	24	24	278
	Between 4·1 and 8 miles ..	..	..	..	..	..	..	10	..	..	..	..	..	10
	Between 8·1 and 10 miles ..	..	..	..	..	..	..	..	..	..	..	..	..	..
	Above 10 miles per hour ..	..	..	..	..	..	..	..	..	..	..	..	..	..

Table X

Total number of hours in each month when the wind velocity is above 4·1 miles per hour

Place and month	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Bangalore ..	744	560	558	570	744	720	744	744	720	310	450	744	7608
Mysore ..	744	476	558	570	744	720	744	744	720	341	540	744	7645
Hassan ..	..	..	186	480	744	720	744	744	720	248	..	..	4586
Chitaldrug ..	434	224	341	480	744	720	744	..	720	248	210	403	6012
Balehonnur ..	..	..	..	..	..	..	310	744	..	..	..	..	310
Jogimatti ..	744	672	744	720	744	720	744	744	720	744	720	744	8760

A Note on Ragi Cultivation in Challakere

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The taluk of Challakere situated in the north-east of Chitaldrug District, is noted for the cultivation of irrigated ragi. The area under irrigation is twenty-two thousand acres. Thirty per cent. of this is under ragi, thirty per cent. under paddy, thirty-five under jola and the rest under miscellaneous crops like onion, chillies, wheat and cotton. In certain years the proportion of the area under ragi increases, but at present owing to a greater demand for jola which is the staple food of the people of this taluk, the area under ragi has decreased a little. The average size of the holding of an individual is just an acre and such of those who own large areas lease out their lands on *Vara* or *Gutta* basis.

The climate of this locality is hot and dry. The mean annual temperature is 70·3° F. The warmest month is April and the maximum temperature at this time is 97° F. In April and May if the summer showers should fail the temperature for a few days may go over 100° F. The highest temperature recorded is 103° F. December is the coldest month of the year with an average of 61·3° F. The lowest temperature on record is 51·2° F.

The annual rainfall is little over 15 inches and in some years it will be as low as 10 inches. Rainy season is from May to November and the heaviest precipitation is during the months of September and October. The relative humidity is 50% in March and 83% in July, August and September. Hot winds, sometimes accompanied by dust storms occur during February, March and April.

Soil is mostly red and sandy. Good, black soils are found in the north-western corners of this taluk. The land surface is gently undulating and is often gravelly. In many villages the soil is impregnated with saline matter. Thus agriculturally the soil may be considered as poor. But the soil in most of the irrigated lands is fairly good. This may possibly be due to years of continuous cultivation and heavy manuring. The soils in these areas are either sandy loam or ordinary loam and fertile enough to bear two crops in a year.

The source of irrigation is entirely from deep wells which are worked by *mhotes* or *kapiles*. The wells are fairly large and have an ample supply of water. Some are large enough to accommodate two or three *mhotes* working simultaneously. Each well can easily command 2½ to 4 acres of land. The depth of wells extends from 30 to 40 feet and the slope of the

ramp or the *mhote* run is 1 in 3 or 1 in 2½. Where a single pair of bullock is worked the ramp is 1 in 5. Each *mhote* is usually worked by two pairs of bullocks. Three or four pairs are not very uncommon. In such cases each pair is made to work in turns, so that the animals are not stretched and the arduous work of lifting water is continued over long hours of about 8 per day. The *mhote* or the *mhotes* start work very early in the morning and work till 10 A.M. After rest and recuperation, work is resumed by about 4 P.M. The *mhote* buckets are of 60 gallon capacity. If the lift is more than 30 feet or when a single pair of animals is used the capacity of the buckets will be 40 gallons. In the case of a single pair, the animals are simply backed up after the bucket is drawn up and emptied. In recent years, some of the affluent farmers have installed pumps worked by oil engines.

There are two main seasons during which ragi is cultivated. The first is the summer extending from February to May but confined chiefly to April and the second is the rainy season during August or September. The nursery work starts twenty days or a month before the seedlings are transplanted. The crop is harvested in 3½ to 4½ months after transplanting depending upon the variety and the season of planting.

Cultivation.—The preparation of the land starts in about six weeks before actual planting takes place. In the first season the preparation of the land commences by about *Sivaratri* (February) and in the second season after the *Rohini* or *Mrigasira* rains—May-June. Throughout this tract ragi is grown only as an irrigated crop and it is mostly transplanted, but sometimes in the second season a broadcast crop of irrigated ragi is taken in stray cases.

Transplanted Crop.—First the seeds are sown in the nursery beds of some convenient size 12 ft. × 4 ft. or 12 ft × 3 ft. The number of beds upon the area to be transplanted. Generally eight or ten beds are put in an area of about one cent. giving enough seedlings for transplanting an acre. The nursery plot is well dug and all the clods are crushed. Farmyard manure or sheep manure or village sweepings is applied to these beds at the rate of two to three baskets per bed and is well worked into the soil. The surface of the bed is levelled and flat beds are prepared surrounded by rim 4 to 6 inches high.

The beds are first splash-irrigated and when in condition seed is broadcast at the rate of ¾ to a seer for each cent. of nursery area. The seeds are covered by sprinkling a mixture of fine soil and manure and by gently working with hand hoes. The beds at this stage are either hand watered or splash-irrigated for about four to six days till the seeds germinate. After this stage the nursery is generally flow-irrigated once in five or six days. The beds are hand-weeded once or twice and the seedlings are thinned in case

of overcrowding. The seedlings are allowed to remain or grow till they are 3–4½ weeks old and attain a height of 6–7 inches.

Concurrent with the raising of nursery beds the preparation of the plot for transplanting seedlings is also taken up. This is done by repeatedly ploughing five or six times with a country plough and working the blade harrow and halube. All the clods are crushed and stubbles and weeds are removed. The whole plot is levelled well. In some cases when the area to be planted is small, the whole area is dug and prepared by manual labour.

After these preliminary preparations the land is splash-irrigated and when the soil conditions permit, farm yard manure is applied at the rate of 15 to 20 cartloads to an acre and worked into the soil. Wherever possible sheep folding is also resorted to. A flock of about one thousand sheep are folded from 6 P.M. to 8 A.M. for one or two nights. The animals are disturbed during nights at regular intervals so that they may urinate freely and leave their droppings freely all over the plot. In the morning the animals are let out and the plot is harrowed so that all urine and droppings get incorporated into the soil. During pre-war days the charges for folding a thousand sheep was three rupees in coin or 60 to 70 seers of ragi in kind per night. At present the charges are five to six rupees a night. The plot that receives sheep-folding receives a correspondingly less dose of farm yard manure. Some of the educated and enlightened cultivators apply oil-cakes and artificial manures at the rate recommended by the Department of Agriculture which will be a mixture of 112 lbs. of groundnut oil-cake, 56 lbs. of fertiliser mixture (80% ammonium sulphate and 20% of single superphosphate) and 56 lbs. of steamed bonemeal or single supers, *i.e.*, a total of 224 lbs. of mixture to an acre. In such cases the fertilisers are applied in the furrows just before transplanting. After working all the farm yard manure into the soil and levelling the plot, furrows are opened at a distance of one foot apart with the help of a country plough or a hand guddali. The irrigation channels are laid at intervals of five feet across the furrows and the whole plot is thus converted into a number of strips each strip having 15 to 20 furrows. In some cases the plot is first made into a number of beds of 30 feet length and 5 feet width and in these beds shallow furrows are opened with a spacing of one foot. Water is let into the furrows through these irrigation channels and is allowed to soak in. At this stage ragi seedlings are removed from nurseries which have received copious irrigation previously to facilitate the easy removal of seedlings with roots intact. These are carefully separated into singles and transplanted in the furrows which are still wet.

There are two methods of transplanting each depending on the season, variety and soil. Generally in the first season on a good soil with a variety which is likely to tiller well, the seedlings are transplanted at the bottom of the furrows. In this case the distance between the rows will be one foot and

from plant to plant it will be about 4 to 6 inches. If the soils are poor and generally in the second season the seedlings are transplanted on both slopes of the ridge. In this case the distance between the rows will be about 7 to 8 inches and from plant to plant about 4 inches. The seedlings establish themselves in five or six days and from then onwards the crop is irrigated once in a week or once in ten days. One or two weedings are given before the crop is a month old, when the whole plot is dug and the rows earthed up by making furrows in between the rows. These furrows are a little deeper than the previous ones and can take in more water. From now onwards the seedlings make a rapid growth and the earheads show up in about a month or a month and a half depending upon the variety. Six weeks later the earheads get mature. Harvesting is done by gathering the earheads as and when they are ripe. In about three or four pickings all the earheads are gathered, heaped up and allowed to cure for three days. Later, all the earheads are spread out on the threshing yard and dried for a day and the grains are threshed by beating with sticks. Some cultivators who have a large quantity to thresh get them trampled by bullocks. The yield of grain varies from 8 to 14 pallas per acre. In the case of ragi that has to be used as seed the earheads are not cured. Curing makes threshing easy and in the opinion of some, it improves the consistency and palatability of the cooked flour or *Mudde*. After the earheads are harvested the plants are grazed down by cattle and sometimes they are cut and made into straw. The straw is considered very inferior and is often used as a thatching. Yield of straw varies from two to five cartloads to an acre.

Though irrigated ragi is mostly grown as a transplanted crop, a small amount of it is also grown by broadcasting. This is generally practised in the case of lands that have recently come under cultivation and in cases where water-supply is inadequate. It is mostly done in the second season; the variety chosen is always *Dodda-ragi*. The preliminary preparation of the land is almost the same as in the case of transplanted ragi. The whole plot is splash irrigated and when the soil is in the optimum condition the plot is worked by a blade harrow and ragi seed mixed with a good quantity of fine manure is broadcast evenly at the rate of about 4 to 6 seers to an acre. The seeds are covered by working a *halube*. Subsequently the plot is converted into a number of beds of 20 ft. by 5 ft. dimensions by opening irrigation channels both length and crosswise. The seeds germinate in about six days and when all the seedlings have emerged, thinning is done by working a small rake-like implement known as *kai-halube*. Sometimes thinning is done by hand and these seedlings are utilised for transplanting other plots. Once in 8 or 10 days the whole plot is splash irrigated. Harvesting and threshing is done in the same way as the transplanted ragi. In this case, the yield of the crop is just half or a little more than that from the transplanted crop.

Cost of cultivation of irrigated ragi at Challakere is noted below:—

	Field operations	Cost	Totals
1.	Preparatory cultivation; 6 ploughings ..	4 0 0	
	Passing harrow and *Halube*	1 0 0	
	Breaking clods and removing stubbles ..	1 0 0	
	Marking beds and irrigation channels.. ..	2 0 0	
			8 0 0
2.	Manures and manuring—20 cartloads of farm-yard manure at 0-8-0 a cart	10 0 0	
	Cost of carting	2 0 0	
	Cost of spreading and working into the soil ..	1 0 0	
			13 0 0
3.	Seedlings and planting—		
	Cost of nursery	3 0 0	
	Pulling out seedling and transplanting ..	2 8 0	
			5 8 0
4.	After care of the crop—		
	Weeding	1 8 0	
	Light earthing up	2 0 0	
	10 irrigations at Rs. 2 per irrigation	20 0 0	
			23 8 0
5.	Harvesting charges	2 8 0	
	Threshing	2 8 0	
			5 0 0
6.	Miscellaneous charges	1 0 0	
	Assessment	2 0 0	
			3 0 0
	GRAND TOTAL..		58 0 0

RETURNS FROM THE LAND

Produce and Particulars	Cost	Total
12 Pallas of ragi at Rs. 5 a palla	60 0 0	
4 Cartloads of straw at Rs. 5 a cartload ..	20 0 0	
Total receipts	80 0 0	80 0 0
Total cost of cultivation ..		58 0 0
Net profit		22 0 0

Looking at the above figures it is seen that the net profit per acre is only Rs. 22. This is taking the value of straw also into consideration. If the straw is left out of consideration the net profit per acre would be only Rs. 2. Then the question naturally arises as to why these people cultivate ragi at such low profits? The answer to this is that Challakere is a tract where rainfall is very low and precarious. The returns from the dry cultivation of food grains is low and very uncertain. The ryot is forced to raise

some food for himself and for his cattle. Moreover he does not pay for all the field operations enumerated above. Most of the manual work is undertaken by his family and the arduous portions are done by men-folk on a co-operative basis. Thus his actual expenses would be just a third of gross expenditure that is shown in the cultivation sheet. Thus he willingly takes the job of cultivating ragi which not only gives him enough food and fodder but also spreads out his labour resources evenly. The receipts and expenses are based on pre-war levels and at present the receipts and expenses would be nearly three-fold.

There are five varieties cultivated in this taluk. They are: (i) *Modur* Ragi, (ii) *Gidda* Ragi, (iii) *Dodda* Ragi, (iv) *Konana Kombu*, and (v) *Kuruba* Ragi.

Modur Ragi.—This is a variety that comes up well both in the first and second seasons. In the first season the nursery is sown in the month of April and the seedlings are transplanted in May. By about three and a half months from the time of planting the crop will be ready for harvest. In the second season the nursery is sown in July and transplanting of the crop is taken up in August. The crop will be ready for harvest by about the middle of December. The yield of crop in either of the seasons would be about 12 to 14 pallas of grain and four cartloads of straw per acre. It is considered that the straw of this variety is good for cattle feed.

Botanically there appears to be two types in this variety, one having green branching earheads, while the other has green compact earheads. The earheads of the branching type are big in size and the plants are very vigorous but the tillering is very poor. In most cases there is only a single stalk with a plump earhead at the tip. The earhead of the green compact type is medium in size, plants carry 3 to 4 tillers and are fairly vigorous. This variety is close transplanted, and it is the combined yield of both these types that make possible, the heavy out-turn of grain and straw.

Gidda Ragi.—This is a single season variety grown only in the first season. The earheads are green compact. The seeds are sown in the nursery by 8th or 10th of April and the seedlings are transplanted by May. This is a little earlier than *Modur* Ragi and will be ready for harvest in the month of August. The yield is 10–12 pallas of grain and 3 to 4 cartloads of straw.

Dodda Ragi.—This also is a one season variety grown only in rainy season. The earheads are green open. Nursery is prepared in the month of July and the seedlings are transplanted by August. The crop matures by the end of December. The yield of this variety both in grain and straw will be as much as Modur Ragi or a little less. But, local people are of opinion that this variety is less hardy than Modur and straw inferior as cattle feed.

Konana Kombu.—This is also grown during rainy season. The earheads are violet open with long incurved fingers. In maturity this is earlier than

Dodda Ragi by a week. The plants make a good growth but lodge badly. The yield of crop is about 12 to 13 pallas of grain and 3 to 4 cartloads of straw per acre.

Konana Kombu at Hebbal is earlier than *Dodda* Ragi by about 10 days. While the grain yield is fair the straw is poor in quality, brittle and yield is also less. Much of the straw is not leafy, containing as it does a large proportion of dry fibrous stalks.

Kuruba Ragi.—This is a variety generally grown during summer. The earheads are violet branching. Yields about 10 to 12 pallas of grain and 3 to 4 cartloads of straw.

Crop Rotation.—Summer ragi is generally rotated with jola, javegodhi, chillies, tobacco, onion and garlic. In the second season if there is enough water in the wells summer paddy is grown as a rotation or if the cultivator thinks that the water is not sufficient for paddy he grows as rotation crops like jola, onion or groundnut.

A statement showing the salient features of the varieties grown in this taluk is appended.

In concluding the writers wish to express their thanks to Dr. L. S. Dorasami, M.Sc. (Lond.), Ph.D. (Lond.), the Economic Botanist, for many valuable suggestions and revising the manuscript.

Statement showing varieties and other features

Variety	Earhead type	Season			Duration including Nursery; No. of Weeks	Yield per acre	
		Nursery	Transplant	Harvest		Grain (Pallas)	Straw (Cartloads)
Modur Ragi ..	Green branching and Green compact	April second week	May first week	September second week	19	14	4
Do.	Do.	July second week	August first week	December middle	20	14	4
Gidda Ragi ..	Green compact	April second week	May first week	August end	18	12	4
Dodda Ragi ..	Green open	July second week	August first week	December end	23	13–14	4–5
Konana Kombu	Violet long incurved	Do.	Do.	Do.	23	12–13	3–4
Kuruba Ragi ..	Violet branching	December second week	January first week	April end	18	10–12	3–4

SELECTIONS

Rice

POTENTIALITIES

It is unnecessary to emphasize again the great number of rice varieties grown and the great number of ways in which rice is cultivated in different parts of India. The present question is the increase of yield and the following remarks deal with that point :

The Report on the Marketing of Rice in India and Burma, 1941, gives the following table based on the results of actual crop-cutting experiments conducted in the provinces mentioned :

	Acreage out-turn of paddy (rice in the husk)	
	Irrigated (lb. per acre)	Unirrigated (lb. per acre)
Madras	1,694	1,138
Central Provinces and Berar ..	1,200	900
United Provinces	1,100	850
Punjab	1,269	587

The all-India average (got by dividing the yield expressed in pounds by the acreage) is as follows during the last five years :

	In terms of rice (lb.)	Converted into paddy (at 66%) (lb.)
1938–39	731	1,098
1939–40	776	1,165
1940–41	680	1,021
1941–42	772	1,159
1942–43	734	1,102
Average of five years ..	738	1,109 lb. paddy per acre.

In India the yields vary considerably from place to place and from province to province as has already been shown in the table given above. In Coorg the ordinary cultivator manages to produce about 1,900 lb. paddy per acre and a certain well-managed Indian estate in Coorg produces 3,800 lb. per acre. In addition to suitable soil and climate the main factors in high yield are (i) use of a high-yielding variety, and (ii) manure and water. Plant-breeders have produced in all the rice-growing provinces varieties which yield from 10 to 25 per cent. more than the local types which they are intended to replace.

Until a few years ago the spread of these new varieties was meagre and it was estimated at only 6 per cent. of the total rice area. This situation was considered by the Imperial Council of Agricultural Research in its Rice Committee and its full Advisory Board and a scheme was devised whereby, within two years, under intensive multiplication, a very large area was to be put under these improved varieties. Following this up in 1941, the Governing Body of the Imperial Council of Agricultural Research allotted Rs. 1,10,000 to be spent in two years for rice schemes, primarily for developing rice cultivation, *i.e.*, introducing improved seed and better cultural practices so as to increase the out-turn per acre. It was hoped by this means greatly to increase the areas under improved rice varieties in certain rice-growing provinces, Madras, Bengal, the United Provinces, the Central Provinces and Orissa. This scheme has been somewhat overshadowed by the 'Grow More Food' drive which aims at increasing acreage and yield of any

variety whatsoever but the participating provinces are continuing with the schemes as a part of an auxiliary to their 'Grow More Food' campaigns.

Given ample water and ample manure there is no doubt that throughout the whole of India, rice yields can be forced very much higher. Manurial experiments carried out in many places and over many years throughout India indicate that Indian yields can be increased very much if fertilizers are available. Increases may be anything from 20 to 150 per cent. according to the variety, soil, climate and season. In the Central Provinces, for example, a dressing of 250 lb. of bone meal and 50 lb. of sulphate of ammonia increased the yield of paddy from 515 lb. per acre to 1,149 lb. per acre, an increase of 128 per cent. In Orissa 110 lb. bone meal in conjunction with green manuring increased the yield from 970 lb. to 1,500 lb., an increase of 54 per cent. At Ratnagiri in the Bombay Province, a dressing of 40 lb. of castor cake per acre increased the yield from 1,250 lb. to 1,670 lb., an increase of 33 per cent. At Pattambi in Madras *neem* cake sufficient to supply 30 lb. nitrogen *plus* sulphate of ammonia sufficient to apply 15 lb. nitrogen increased the yield from 1,481 lb. per acre to 1,806 lb. per acre, an increase of 22 per cent. These are only a few examples from a very long record. The important thing is that fertilizers must be cheap relatively to the value increased produce, *i.e.*, the additional paddy produced by the use of fertilizers.

At Sabour in Bihar experiments carried on over three years showed that 100 lb. of sulphate of ammonia containing 20 lb. of nitrogen gave an increase of 466 lb. of paddy per acre. Paddy was then selling at Rs. 2 per 80 lb. The increased price of this grain was Rs. 11–10–4, cost of the manure was Rs. 5–5–0, the increase of straw of 869 lb., valued at Rs. 2–11–5 ; so the net profit on the manuring was Rs. 9. Oil-cakes and green manure gave similar results, and it is largely a matter of choosing a manure for the paddy crop which is the most available and the most economical. Rice needs phosphorus as well as nitrogen, and where this has been added either as bone meal or superphosphate, still further increases have been obtained.

It is obviously not economical to manure if the price of the manure added is going to be greater than the value of the additional paddy obtained.

Mr. E. F. Sykes of the Bundi Agricultural Syndicate, Ltd., has carried out for the last three years experiments on rice manuring on his farm near Bundi. The general results are that for every 60 lb. of sulphate of ammonia added, there is an addition of 4 maunds of paddy (approximately 330 lb. per acre). This holds up to 180 lb. sulphate of ammonia per acre. Even with sulphate of ammonia at a very heavy price, *i.e.*, Re. 0·6 per lb. of nitrogen or Rs. 269 per ton (*i.e.*, Rs. 13·44 per cwt.) such manuring was profitable, with paddy selling at Rs. 4 per maund giving a profit of Rs. 26·52 per acre and with paddy at Rs. 5 per maund gave a profit of Rs. 38·55 per acre. Similar results were got by giving similar amounts of nitrogen as castor cake.

Experiments on the economics of fertilizing paddy with sulphate of ammonia carried on over many years by the Imperial Chemical Industries throughout India show almost everywhere both a very marked effect on the fertiliser and a good return on fertilizer expenditure. Experiments carried on in Bengal between 1936 and 1939 show the average increase in yield from applying one maund (80 lb.) sulphate of ammonia to have been 4·01 maunds (80 lb.) grain and 9·45 maunds straw, with the dressing of 1½ maunds (80 lb.) costing Rs. 7–4–0 giving an increase of 6 maunds grain and 14·18 straw. Valuing the paddy at

Re. 1–11–0 per maund (80 lb.) and the straw at 8 annas a maund (80 lb.), the value of the increased yield was Rs. 12–13–0, the net profit per acre being Rs. 5–9–0 and the return on fertilizer expenditure 76 per cent. Even if the paddy had sold as low as Re. 1–6–0 per maund (80 lb.) there would still have been a 50 per cent. profit on the fertilizer expenditure.

In other parts of India, the average increase in yield from applying one maund (80 lb.) sulphate of ammonia, varied from 1·99 maunds paddy in the Punjab to 4·42 maunds in Madras. For the whole of India (the average of 34 centres) where experiments were carried out between 1933 and 1939, the average increase in yield from applying one maund (80 lb.) of sulphate of ammonia was 3·44 maunds (80 lb.) grain and 7·26 maunds (80 lb.) straw. The cost of the fertilizer, applied 1½ maunds (80 lb.), was Rs. 7–5–0. The value of the produce per maund (80 lb.) was taken as Rs. 2–4–0 per maund grain and 4 annas per maund straw, the value of increased yield was Rs. 14–6–0, the net profit per acre Rs. 7–1–0 or 97 per cent. on the fertilizer expenditure. Even with the paddy selling at Re. 1–10–0 per maund (80 lb.), there would have been a return of 50 per cent. on the fertilizer expenditure.

There is therefore everything to be said for the increasing and cheapening of supplies of all types of oil-cakes and of bone meal and for the encouraging of green manuring previous to the planting of rice crops. The actual manures to be given and their quantities must be determined by the Agricultural Department of each Province or State for its own particular climatic, geographical, industrial and price conditions, but the information exists and has only to be applied.

Taking India as a whole we shall take the conservative figure of a probable increase of 30 per yield per acre of which we shall consider 5 per cent. due to improved variety, 20 per cent. due to increased manuring and 5 per cent. due to protection from certain pests and diseases. The manuring later suggested is capable of giving at least a 40 per cent. increase and the improved varieties could give a 10 per cent. increase; but these figures are halved to make the estimate conservative. Averaging the all-India area and yield for the years 1924–25 to 1940–41 to the nearest hundred thousand acres and tons we get an area of Rs. 76,300,000 acres and 28,000,000 tons. An increase of 30 per cent. on this would be an addition of 8,400,000 tons or a total of 36,400,000 tons, a figure which has not been reached in peak years though in 1917–18, the all-India total may be estimated at about 33,000,000 tons.

To get this result we assume (i) the use of no seed except that of high yielding varieties, to be made available under comprehensive seed schemes. Each seed scheme would be based on the plant breeder's plot, the seed being multiplied first at the Government Farms and then on the farms of registered growers.

To get this amount of seed it is obvious that there would have to be more than one series of registered growers, probably at least three such series, the later series getting their seed from earlier ones, the whole process being supervised right through with the necessary rogueing of the crop in the field, buying and storing all the seed at each stage and final distribution to the cultivator. The cultivator is rarely prepared to pay more than ordinary market rates even for improved seed (though there have been exceptions to this) and while the seed schemes are developing they would have to be subsidised by grants to registered growers and for storage and transport somewhat in the manner devised for the already mentioned Imperial Council of Agricultural Research schemes for the quick spread of improved rice varieties.

As regards adequate supply of manure, let us assume manuring equal to one ton of any type of oil-cake to five acres with an average nitrogen content in the oil-cake of 5 per cent. giving 22·4 lb. nitrogen per acre (equivalent to one cwt. of sulphate of ammonia). For 76,300,000 acres this would mean 15,260,000 tons of total oil-cakes. The actual amount of all oil-cakes produced in India at the moment is not known. Considering oilseed production, it may be of the order of 3 million tons.

It is not, however, necessary or feasible to apply this nitrogen entirely as oil-cakes. It might be supplied partly as bone meal, partly as sulphate of ammonia, partly as farmyard manure or green manure.

Let us assume for the purpose of argument that the nitrogen supply for rice is divided equally between these five sources. Each of these sources will then have to supply the equivalent of 3,052,000 tons of oil-cakes. Let us assume the following nitrogen contents :

	Per cent.
Bonemeal	4
Sulphate of ammonia	20
Farmyard manure or compost	0·5 (a low estimate)
Green manure	0·7

(average for 40 varieties with 75 per cent. moisture content).

We get the following tonnages required :

	Tons
Oil-cakes	3,052,000
Bonemeal	3,815,000
Sulphate of ammonia	763,000
Farmyard manure or compost	30,520,000
Green manure	21,800,000

Insect pests.—As regards reduction of pests and diseases, the chief insect pest in South, Central and Western India is the rice grasshopper, *Hieroglyphus banian*. This is most effectively dealt with by running large bags over the crop while young. Destroying the egg masses by scraping the *bunds* and ploughing up the fields during early summer months is also useful. This involves the making of bags and a certain amount of labour. The other important pests in India and their methods of control are :

(i), (ii) The swarming caterpillar and the army-worm (*Spodoptera mauritia* and *Cirphis unipuncta*). Practicable methods of control are the flooding of the infested nurseries. This brings up the hiding caterpillars which are eaten by birds. The use of trenches round the infested seed-beds to prevent the migration of the pests from one infested field to another is also useful.

(iii) The paddy stem borer (*Schænobius species*). While transplanting, seedlings showing dead-hearts should be removed. Light traps attract a large number of female moths and thus reduce the population. The stubble after harvest should be ploughed up and destroyed because the pest lives as larva or pupa in this refuse and subsequently attacks the fresh crop.

(iv) The rice hispa (*Hispa armigera*). It is especially abundant in South India, Assam and Bengal. This beetle can be best controlled in the seedling stage when infested leaf tips which contain young stages can be clipped off before transplantation.

Other pests are the rice bug chiefly found in Eastern India and the paddy gall-fly common in Madras and Mysore.

Fungus diseases.—There are two very important fungus diseases of rice which cause serious damage ; two which cause less damage and several minor ones. Most serious is *Helminthosporium Oryzæ*, which attacks leaves and seeds. It is partly seed-borne and partly

air-borne. Disinfection of seed with mercurials reduces infection in the seedling stage, but mercurials are expensive and difficult to secure at present; so does immersion of the seed in hot water, though it is very risky to do it, owing to great danger of killing the seed, unless accurate machinery is used by skilled operators.

Blast, caused by *Piricularia Oryzæ*, is serious in most parts of India. A rice variety known as Adt. 6 has been found to be highly resistant in Madras, but the varieties Co. 4, Co. 11 and GEB 24, once thought to be highly resistant, are now found to be susceptible under certain conditions. In Assam the varieties Thabora and Zoulake are thought to be resistant. In Madras, when paddy has been sown in September, late-flowering varieties suffered less than early-flowering ones. Sowings made in November suffered less than those in September and October.

Fusarium moniliforme causes a serious foot-rot disease. The fungus *Ustilaginoidea virens* causes an infection of individual flowers resulting in replacement of the developing grain by a hard sclerotal mass. Neither of these diseases can be controlled by any methods known at present. Some minor diseases of rice are smut, caused by *Tilletia horrida*, leaf smut caused by *Entylema Oryzæ*, and stem disease by *Ephelis Oryzæ*.

Water.—Improvement of wter supply will vary immensely in its nature, cost and scope in different parts of India. In certain areas, it will mean the extension of an existing canal system or the establishment of a new one, in others the digging of tube wells, in others pumping from rivers and in others the construction of simple reservoirs. So far as rice is concerned, the effect of such increased water supply would be more to extend the area under rice than to increase the acre yields. Even with the increases now mentioned, India is a good way off the existing acre yield averages of certain other rice-growing countries, *i.e.*, the estimated 36,400,000 tons cleaned rice got from 76,300,000 acres works out at 0·48 ton per acre. The average yields per acre of certain other countries are as follows :—

Approximate yields of rice in important countries of the world
(lb. per acre)

	Average 1909–13	Average 1926–27 to 1930–31	Average 1931–32 to 1935–86	1936–37	1937–38	1938–39
India (including Burma) ..	982*	851	829	861	826	728
Burma ..	..	887	845	833	813	959
Indo-China ..	928†	661	637	..	..	..
Siam ..	..	1,017	691	863	829	943
United States of America	1,000	1,333	1,413	1,505	1,471	1,469
Italy ..	1,952	2,797	2,963	2 839	3,258	2,903
Spain ..	2,969	3,749	3,709	..	..	..
Egypt ..	2 119	1,845	1,799	2,083	2,001	2,153
Japan ..	1,827	2,124	2,053	2,339	2,305	2,276

* 1914–15 to 1918–19 † 1912–13 to 1913–14

There is absolutely no reason why India should not aim at an average yield of 1,000 lb. cleaned rice per acre or a total production of the order of 34 million tons.–*From Technological Possibilities of Agricultural Development in India* (1944), A Note by W. Burns, C.I.E., D.Sc.

767-48 Printed at The Bangalore Press, Bangalore City, by G. Srinivasa Rao, Superintendent